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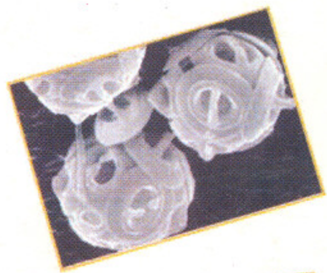
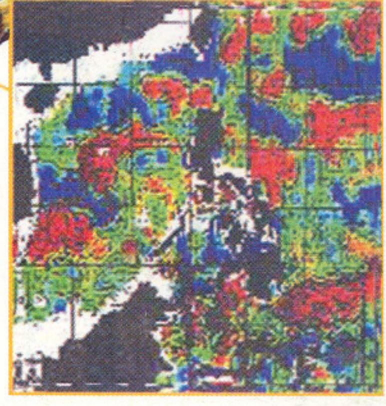


FOOD Chain in the SEA -Its Values, CHALLENGES & PROSPECTS



FOOD CHAIN IN THE SEA-ITS VALUES, CHALLENGES AND PROSPECTS

By
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1. INTRODUCTION

The planet world had a population of 4 billion in the year 1975, since then its population is ever increasing at a tremendous rate and by the year 2025 it is estimated to reach 8 billion. The land usage on the earth surface is almost exhausted while its arid coverage is ca 43.5% of the earth surface. As such, human being has no alternative but inevitably has to go to the sea which covers >75% of the earth surface, for food sources in the near future.

Since 1980, Malaysia has been given the sovereign rights in her exclusive economic zone (EEZ) for the purpose of exploring, exploiting, conserving and managing the natural resources (whether living or non-living) sea bed, subsoil and adjacent waters within 312 km of the waters adjacent to her coast. Thus, Malaysia acquired 332,673 sq km (4 times her land area) of the sea around her for the purpose of exploring natural resource development and management. The continental shelf as well as the coastal inshore waters (lagoons, bays, estuaries, mudflats, mangroves) are quite extensive especially estuarine or brackish water, mangroves, lagoons and other types of water bodies which are common features found all around the coastal region of Peninsular Malaysia. Many of these water bodies which are regarded as, important natural breeding and nursery grounds for marine or brackish water organisms (especially fish) could be utilized as potential fish culture areas.

There is a general relationship between primary production of phytoplankton and the abundance of zooplankton and organisms higher up the marine food chain (Shamsudin & Shazili, 1991; Shamsudin & Sleigh, 1993, 1995). However, a representation of the food pyramid in the sea in which there are many tropic levels is probably a more accurate representation of what is actually going on than the simpler representation of a food chain. The coastal waters of the world oceans are usually productive (>150 g C/m^2/y primary productivity) especially in upwelling areas having short food chain (1.5 - 2) and the fish production is also high (120x10^6 metric ton/y) (Table 1).

This presentation attempts to make a closer examination of the potential exploitation of the various organisms in the food chain as sources of high nutritive food/

feed added values for animal/human consumption. At the same time, this presentation will also highlight the practical applications, prospects and challenges of potential food product development derived from these aquatic organisms in the food chain. Finally, this will be followed by discussion on the general applications, its values and implications of the food chain in the wide ocean as an overview.

2. FOOD CHAIN IN THE SEA - ITS IMPLICATION

A simplest food chain in the marine ecosystem involves the primary producers (namely phytoplankton, algae) which are directly utilised by all growth stages of bivalve, by larval stages of some crustacean species and by the early growth stages of some fish species (Fig. 1). Efforts are being made to isolate wild species of these potential algae (namely Diatom - *Skeletonema, Navicula; Chaetoceros;* Prasionphyta - *Dunaliella, Nanochloris, Chlamydomonas, Chlorella, Tetraselmis;* Prymnesiophyceace - *Emilíania, Gephyrocapsa, Isochrysis;* Cyanophyta - *Spirulina*) from various aquatic ecosystems and subsequently cultured them under the controlled environmental condition in the laboratory or in the out-door mass culture (Table 2). Algae are also used in aquaculture to rear mass quantities of zooplankton (rotifers, copepods and brine shrimp) for late-larval and juvenile stages of crustaceans and fish (Ackman *et. al.*, 1964; Shamsudin *et. al.*, 1996 & 1997; Shamsudin, 1992; Shamsudin *et. al.*, 1998, 1999). In nature, the nutritional value of algae in this zooplankton food chain is also critical, since essential algal nutrients are passed on via the intermediately zooplankton to the organisms higher up in the food chain (Shamsudin, 1992; Syed *et. al.*, 1999). The protein, carbohydrate, lipids and minerals make up 90 - 95% of the dry weight of the algae while the remainder is accounted for by the nucleic acids (5 - 10%). The lipid comprises of the polar groups (namely phospholipid, glycolipid) and the neutral groups (triglycerid, diglycerid, cholesterol, pigment, hydrocarbone, alkenones and pigments). Variables such as photoperiod, light intensity, colour (wavelength), temperature, type of nutrients and stage of growth can influence gross composition of the algae. The Japanese people consume high amount of microalgae (*Chlorella, Spirulina*) as essential health food sources from the sea; as such short circuiting the natural marine food chain in the sea.

Table 1: Primary productivity and fish production in the ocean

Region	Primary Productivity 10^9 metric ton Organic Carbon/y	Production g $C/m^2/y$	Tropic Level	Ecological Efficiency %	Fish Production Fresh Weight x 10^6 metric ton/y
Open Water (oceanic)	16.3	<50	5	10	1.6
Coastal water	3.6	>150	3	15	120
Upwelling	0.1	300	1.5	20	120
Total	**20**				**240**

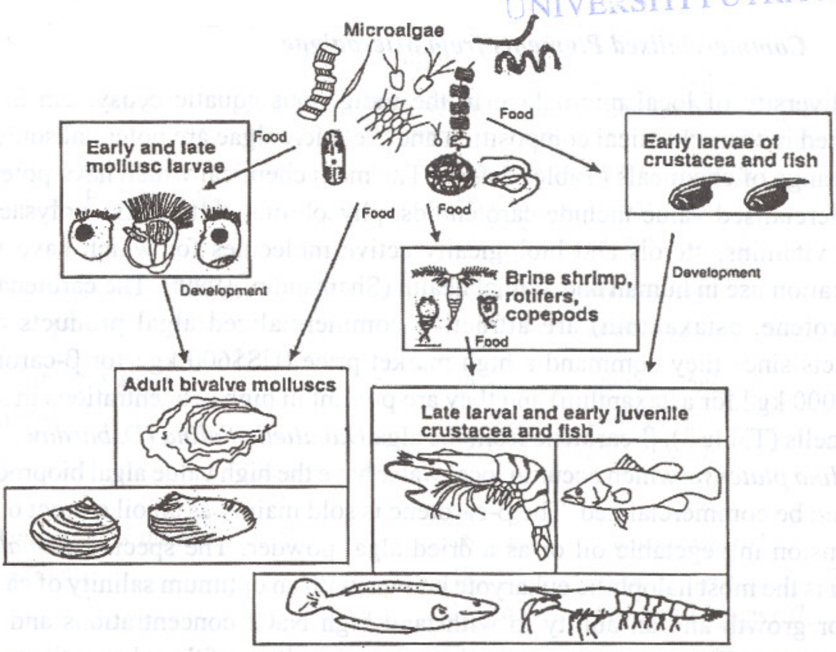
2.1 Microalgae as Live Food

Microalgae (the primary producers) have an important role in aquaculture as live food for larval stages of many species of crustacean and fish, as well as for all stages of bivalves and as food for the zooplankton (rotifers, copepods, brine shrimp), which are eventually fed to late larval and juvenile fish and crustaceans in hatcheries (Renaud *et. al.*, 1991; Shamsudin, 1992, 1993[abc], 1994[ab], 1997[a]). A sufficient quantity and quality of microalgae have to be grown in mass culture under local condition in hatcheries. Subsequently these live food organisms are fed to the early stages of certain prawn, especially *Penaeus monodon* Fabricius, which is an important commercial species in Malaysia shrimp aquaculture (Shamsudin, 1992). Most marine animals have only a limited ability to synthesise the polyunsaturated fatty acids (PUFA) 20:5ω3 (eicosapentaenoic acid, EPA) (Fig. 2) and 22:6ω3 (docosahexaenoic acid, DHA (Fig. 2) from precursor fatty acids such as linolenic acid (Kanazawa *et. al.*, 1979). The presence of PUFA components are essential in commercial species of penaeid prawns and shrimps (Kanazawa, 1985) and species of oyster (Langdom & Waldock, 1981). However, some aquatic animals may not have an absolute dietary requirement for eicosapentaenoic and docosahexaenoic acids, but growth rates and larval survival usually increase when these fatty acids are included in a diet derived from cultured microalgae (Rodger & Barlow, 1987).

Some of the common phytoplankton species used as live food for the commercialized mollusc cultured species include those of the diatoms, the green flagellates

(Prasinophytes, Prymnesiophytes, Chlorophytes, Cryptomonads) and even the paradoxically species of dinoflagellates, all of which occur naturally in our aquatic ecosystem (Shamsudin, 1995[a]). There is at least 5 local species of bivalves (*Crassostrea belcheri* Souerby, *C. iredalei* Faustino, *Saccostrea cucculata* Born, *S. echinata* Quoy & Gainard, *Ostrea folium* Linnacus, *Hyotissa hyotis* Linnaeus) awaiting to be commercialized. Apart from that, the ecosystem offers great variety of microalgal species which have potential to be isolated and being mass cultured as live food organisms. The nanoplankton *Emilionia huxleyi* and *Gephyrocapsa oceania* which has been found to be high in its nutritional values, are available in the South China Sea pending to be commercially utilised. These two coccolithopnorid species have also wide application in water mass identification of the ocean as biological indicator studies in ocean circulation. In addition, some microalgae (*Chlorella, Spirulina*) are consumed directly by human in the form of tablets and pills (Shamsudin *et al.*, 1999[c]).

The nutritional quality of the microalgae needs to be maintained at optimal condition in order to ensure the maximum growth and survival rate of the cultured animals (Volkman *et al.*, 1989). Besides, nutritional value of the microalgae is usually related to their biochemical composition, especially lipids and fatty acids (Chu & Dupuy, 1980; Watanabe *et al.*, 1983; Ahlgren & Boberg, 1992; Shamsudin, 1992). Green algae are low in the monounsaturated (5 - 20%) but high in the polyunsaturates (50 - 80%); whereas prymnesiophytes and diatoms have similar levels of both the monounsaturate (20 - 40%) and polyunsaturate (20 - 50%) fraction (Watanabe *et al.*, 1983, 1984; Shamsudin, 1992). The polyunsaturate fraction of green algae, however, is dominated by 16 and 18 carbon chain-length fatty acids, whereas levels of the higher carbon fatty acids (e.g. 20:5ω3 and 22:6ω3) are typically lower than those of other algal groups. Despite these natural typical trends, the levels of specific fatty acids may vary widely in closely related species in the same class. In particular, differences in the levels of the polyunsaturated fatty acids (FUFAs) 20:6ω3 and 22:6ω3 are important in the nutrition of maricultured animals.



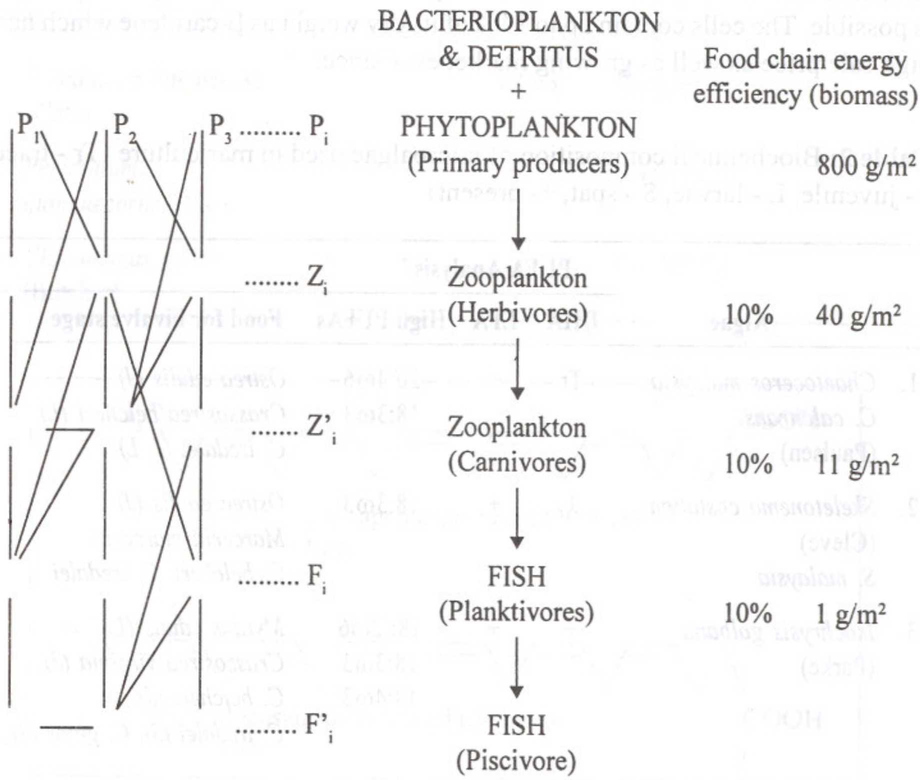


Figure 1: Food chain involving five trophic levels

2.2 *Commercialised Pigments from Microalgae*

The diversity of local microalgae in the indigenous aquatic ecosystem is also reflected in their chemical composition and the microalgae are potential source of wide range of chemicals (Tables 3 & 4). The main chemical which have potential commercialised value include carotenoids, phycobilins, fatty acids, polysaccharides, vitamins, sterols and biologically active molecules for which have wide application use in human and animal health (Shamsudin, 1999[e]). The carotenaoids (β-carotene, astaxanthin) are attractive commercialized algal products algal products since they command a high market price (US$600 kg^{-1} for β-carotene; US$3000 kg^{-1} for astaxanthin) and they are present in high concentrations in some algal cells (Table 3). β-carotene from the alga *Dunaliella Salina (D. bardawil)* and *Spirulina platensis* which occur in local water have the high value algal bioproducts that can be commercialized. The β-carotene is sold mainly as an oil extract or as a suspension in vegetable oil or as a dried algal powder. The species, *Dunaliella salina* is the most halophilic eukaryote known, with an optimum salinity of ca 22% ppt for growth and an ability to withstand high NaCI concentrations and high temperatures. This means that extensive open-air culture of this alga in the tropics is possible. The cells contain up to 14% of its dry weight as β-carotene which has a high sale price as well as growing market ever since.

Table 2: Biochemical composition of microalgae used in mariculture (Tr - trace, J - juvenile, L - larvae, S - spat, +- present)

Algae	PUFA Analysis			Food for bivalve stage
	DHA	EPA	High PUFAs	
1. *Chaetoceros malaysia* *C. calcitrans* (Paulsen)	Tr	+	20:4ω6 18:3ω3	*Ostrea edulis (J)* *Crassostrea belcheri (L)* *C. iredalei (J, L)*
2. *Skeletonema costatum* (Cleve) *S. malaysia*	+	+	18:3ω3	*Ostrea edulis (J)* *Marceria marceria* *C. belcheri, C. iredalei*
3. *Isochrysis galbana* (Parke)	+	+	18: 2ω6 18:3ω3 18:4ω3	*Mytilus edulis (L)* *Crassostrea virginia (J)* *C. belcheri (J)* *C. iredalei (J), C. gigas (J)*

Algae	PUFA Analysis DHA	EPA	High PUFAs	Food for bivalve stage
4. *Emilionia huxleyi* (Lohm.) Hay & Mohler	+	Tr	18:3ω3 18:4ω3 18:5ω3	*Mytilus edulis (L)* *Ostrea edulis (L)* *Ostrea edulis (L)*
5. *Gephyrocapsa oceanica* (Kamptner)	+	Tr	18:3ω3	*Mytilus (L)* *Ostrea (L)*
6. *Tetraselmis suecica* (Butcher)	Tr	+	16:4ω3 18:2ω3 18:3ω3 18:4ω3	*Mytilus edulis (J)* *Ostrea edulis (J)* *Ostrea edulis (S)*
7. *Nannochloris atomus* (Batcher)	Tr.	+	16:3ω3 18:2ω6 18:3ω3	*Strombus gigas (L)* *Tridacna gigas (L, J)* *Hippopus hippopus (L, J)*
8. *Protoperidinium* sp. (Bolech)	+	+	18:3ω3	Bivalve (L)
9. *Pyrodinium bahamense* (Plate)	+	-	18:4ω3	Bivalve (L)
10. *Peridinium quinquecorne* (Abe)	+	+	?	Bivalve (L)
11. *Chroomonas salina* (Butcher)	+	+	?	Bivalve (L)

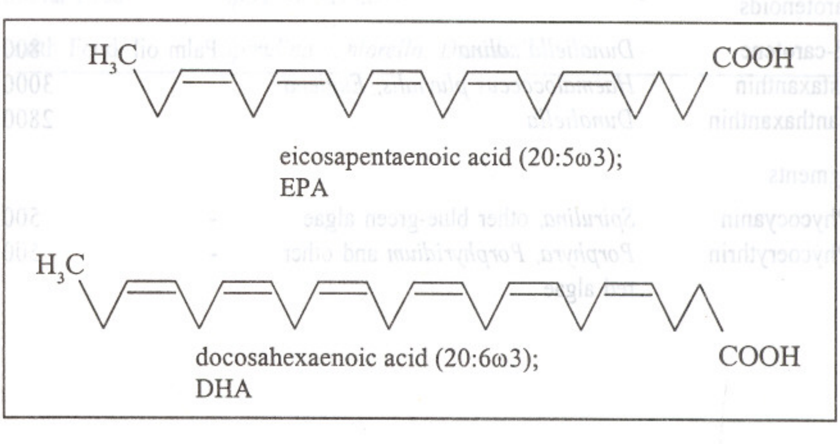


Figure 2: Structure of EPA and DHA

3. INDIGENOUS ZOOPLANKTON SPECIES AS LIVE FOOD

The next higher group in the food chain immediately after the primary producers microalgae is the herbivorous zooplankton. Traditionally, the zooplankton brine shrimp (*Artemia*) have been cultured in large quantities and used as food organisms in Malaysian aquaculture for rearing of commercial fish larvae. Indigenous zooplankton copepod species (especially *Oithona* sp) readily available from numerous coastal waters of the South China Sea, can be substituted for brine shrimp as food organisms (Shamsudin & Shazili, 1991; Shamsudin, 1992, 1993[abc], 1994[a], 1994[b]). Copepod has a similar size range (150-350 μm) to that of *Artemia* and is thus suitable for fish larval rearing during the juvenile stage. A series of sieve nets (ranging from 100 to 400 μm) can be used to trap these copepods. A plankton bloom usually occurs annually (especially from February to April) in these coastal waters, immediately after the mixing of turbulent waters in the sea (Shamsudin *et al.*, 1995; Shamsudin, 1997). This mixing bring nutrient-rich deeper waters to the surface and thus stimulates the plankton bloom which develops quickly, with copepod being the major species in the zooplankton community. The food value of any potential food organisms is again related to their biochemical composition, especially lipid and fatty acid contents (Ackman *et al.*, 1980; Chu and Dupuy, 1980; Watanabe *et al.*, 1982, 1983).

Table 3: Commercialised products from microalgae (USD-US Dollar, DW-Dry Weight)

Algal Product	Source	Alternative Sources	USD/kg DW
1. Carotenoids			
β-carotene	*Dunaliella salina*	Palm oil	800
astaxanthin	*Haematococcus pluvialis, Euglena*		3000
canthaxanthin	*Dunaliella*		2800
2. Pigments			
Phycocyanin	*Spirulina*, other blue-green algae	-	500
Phycoerythrin	*Porphyra, Porphyridium* and other red algae	-	500

Algal Product	Source	Alternative Sources	USD/kg DW
3. Polyunsaturated Fatty Acids (PUFA)			
Eicosapentaenoic Acid (EPA)	*Skeletonema, Chaetoceros, Porphyridium,* Prymenesiophytes, *Cryptommonads*	Fish oil	1200
Docosahexaenoic Acid (DHA)	Prymnesiophytes, *Cryptomonads*	Fish oil	1200
4. Polysaccharides			
Polysaccharides	*Prophyridium, Spirulina*	Bacteria	-
5. Vitamins			
Tocopherol	Brown algae	Soy beans,	1400
Vitamin B_{12}	Various algae	Peanuts	1200
β-carotene (Pro-Vitamin A)	*Dunaliella salina*	Bacteria Palm Oil	1200
6. Bioactive Compounds			
Anti-fungal, anti-bacteria, anti-viral, anti-neoplastic	Many algal species	?	?
7. Aquaculture Feed	Diatom, blue-greens, *Spirulina,* Prasino/Prymnesiophyta	?	?
8. Animal Feed	*Spirulina,* Diatom	-	-
9. Health Food	*Spirulina, Chlorella, Dunaliella*	-	-

Table 4: Estimated value of algal biomass, based on product value and cell content (USD-US Dollars).

Alga	Product	Cell Content (% dry wt)	Value of Product (USD kg^{-1})	Value of Alga (USD kg^{-1})
1. *Chlorella* sp. (Butcher)	Health Food	100	25	25.00
2. *Dunaliella* sp. (Butcher)	Glycerol	40	2	0.20
	β-carotene	10	600	30.00
3. *Haematococcus pluvialis* (Rostaf)	Astaxanthin	1	3000	30.00
4. *Spirulina platensis* (Kutz.)	Phycocyanin	2	500	10.00
5. *Phaeodactylum tricornutum* (Bohlin)	Eicosapentaenoic acid (EPA)	0.1	1900	190.00

At present in the international market, there is a need to increase the β-carotene productivity by increasing growth rate and reliability and by improving the β-carotene content of the cells. The long chain algal polyunsaturated fatty acid arachidonic acid (AA), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are of commercial value. *Porphyridium cruentum* can contain >30% of its total fatty acids as AA and equally high concentrations of EPA. The diatom, *Phaeodactylum tricornutum* contain more than 35% of the total fatty acids as EPA. DHA is more abundant in prymnesiophytes such as *Isochrysis* and *Pavlova* and in the cryptomonad *Chroomonas salina.* The paradox is that some of the so called local toxic dinoflagellates (*Protoperidinium* sp., *pyrodinium* sp.) may content high PUFA.

4. LOCAL *SPIRULINA* AS SUPPLEMENTARY FEED OR FOOD

One a commercial basis, *Spirulina* is grown in coastal ponds in Hawaii, using sea water which is pumped out from the deep ocean surrounding the island. The local algal species *Spirulina platensis* is a micro-alga rich in protein, vitamin B complex, β-carotene, carotenoid, iron, PUFA especially gamma-linolenic acid (GLA) and phycocyanin. Clinical studies with *Spirulina* have revealed new health benefits ranging grom radiation protection, anti cancer, anti-viral properties, cholesterol reduction and reduction of nephrotoxicity by heavy metals. *Spirulina* increases growth rate, fertility, survival rate and colouration of fish. Various grades of naturally micro-encapsulated *Spirulina* are used widely in hatcheries as feed for fish fry and shrimp.

The first photosynthetic life form, the blue green algae were in existence since 3.6 billion years ago. Blue-green algae, cyanobacteria, is the evolutionary bridge between bacteria and green plants. It contains within it everything life needed to evolve. This immortal plants has renewed itself for billions years and it has 3.6 billion years of evolutionary wisdom coded in its DNA. This strain is dispersed to other localities by water birds (eg. flamingos).

We have made extensive collection of *Spirulina platensis* and *S. maxima* in UPMT from indigenous local environments and various localities around the world. Several strains have also been acquired from major culture collection agencies. The major determinants in the selection of strains for commercial production are growth rate, biochemical composition and resistant to mechanical stress.

The outdoor cultivation of *Spirulina* today is carried out in raceways, mixing being provided by paddle wheels or in polyethylene bags or tubes. The tubes obviously function as solar collectors. Daily productivity in the tubes has reached 15 g (dry weight)/m^2. Other advantage of the tubular system is the considerable reduction of water loss by evaporation.

The dried *Spirulina* powder is sold as a human food supplement, as food colouring and as animal feed (cattle, domestic cats), particularly for shrimps and fish. Maintenance of high quality cells requires good management practices during culturing, harvesting, drying and packaging. *Spirulina* is usually grown in shallow ponds (12-15 cm depth) with paddle wheels to aerate the water and subsequently being concentrated into thick paste by serial filteration.

Spirulina is a thermophilic alga and the optimal temperature for its growth being relatively high. The optimal temperature range is between 35 to 40°C. *Spirulina* can tolerate 7 g of NaCl (seawater) and 50 g $NaHCO_3$/L without measurable ill effects; this tolerance reflecting the conditions in the natural habitat of this alga. High alkalinity is required for the growth of *Spirulina* as reflected in the pH (8 to 10) optimum for its growth. The higher the pH that is to be maintained in the pond, the greater the proportion of carbonate. Ammonia or urea, is used in a large-scale culture operations. Phosphorous could be well supplied as phosphoric acid. A turbulent flow in the pond is the key factor for obtaining high output through a better utilization of the irradiant flux reaching the pond surface.

5. MARINE LOCAL FISH OIL AS HEALTH FOOD

The organisms high up in the food chain after the herbivore are the predominantly larger size carnivore such as fish. Clinical studies conducted on Greenland Eskimos and several fish eating Japanese populations showed very little incidence of coronary heart disease among these people (Dyerberg *et al.*, 1975 Dyerberg and Bang. 1979; Dyerberg, 1982; Kagawa *et al.*, 1982; Boberg *et al.*, 1985; Palamblad, 1990). Their observations have correlated well with high intake of fish (eel, mudskipper, sharp, pelagic and demersal marine fish) and aquatic organisms especially of marine origins in their diet. The marine products consumed by these people are rich in polyunsaturated fatty acids (PUFA), particulary in the eicosapentaenoic acids (EPA, C22:5ω3) (Shamsudin *et al.*, 1996[ab], 1999[abc]). The effects of these acids on chronic diseases are well documented (Dynerberg *et al.*, 1978; Jones & Davies, 1982; Kenneth, 1986; Simopoulus *et al.*, 1986; Kinsella, 1988). Recent research has shown that polyunsaturated fish oils could lower serum triglyceride and cholesterol levels and also help to prevent blood clotting (Dynerberg, 1986; Connor & Connor, 1986; Herold & Kinsella, 1986). The arachiodonic acid, an essential precursor for the production of prostaglandin which is the localized regulatory hormone controlling various physiological functions of our body.

Selected species of Malaysian marine fish had been analysed for their oil, lipid and other biochemical contents (Shamsudin, 1995, 1998). The result showed some local species of the marine organisms contained significantly high levels of unsaturated fatty acids compared to saturated acids. The omega-3 acids were generally high in most species analysed especially for the eel (linang), bawal hitam and mudskipper, all of which contained significantly high level in C22:6ω3. This quantity is comparable to that of salmon, cod and herring and warrants conside-ration for commercial exploitation. Cholesterol fractions of these three fish analyses were low.

Fish oil is used in a variety of product covering food, livestock feeds, pet foods, aquaculture feeds and industrial markets. Fish oil is a great source of omega-3 fatty acids for food enrichment. The features and benefits from fish include firstly, it provides 24 - 28% long chain omega-3 fatty acids, being environmentally friendly, alternative high energy source, skin and coat conditioning for animals, improved immune response, improved reproductive performance, reduction in inflammation, excellent drying and emulsifying properties, hydrogenated form provides a wide array of cooking fats and high omega-3 to omega-6 ratio.

This fish oil product can also be made specifically for cattle, sheep, goats, chicken and other ruminants, requiring bypass protein. It has also been specifically developed for pet food and aquaculture where low levels of ash help to improve animal health and/or reduce pollution.

5.1 Local Marine Eel as High PUFA Source

The total lipid contents in the *Anguilla mauritiana* (ikan linang) flesh was significantly high with values ranging from 280 to 430 mg/g dry weight (DW) (Shamsudin *et al.* 1996[c]). The eel major fatty acid contents also showed high concentration of 20:4ω6 (arachiodonic acid, AA), 20:5ω3 (eicosapentaenoic acid, EPA) and 22:6ω3 (docosahexaenoic acid, DHA) (Shamsudin *et al.*, 1999[c]). The liver and the flesh of the eel had high content of DHA (91 mg/g DW). The saturated fatty acids were low. The cultured species, *A. japonica* is fed with highly nutritionous feed in the form of soft paste in commercially operated culture ponds. The selected eel species can be taxonomically screened and identified through finger printing technique. Current studies in the genetic finger printing of eel include various aspects of genetic/phylogenetic variation among wild and cultured population, the model inheritance of economically desirable traits in various species and genetic resource as well as the development of new breeding techniques are specially noted.

5.2 Local Mudskipper as Rich Source of PUFA

Local mudskippers collected from mudflats of Pengkalan Chepa, Kelantan had also been shown to possess potential health properties (Shamsudin 1998). The dominant mudskipper species in the mudflat community comprising of *Periophthalmodon schlosseri* and *Periophthalmus vulgaris*, accounted for more than 80% of the mudskipper population. The major fatty acid contents of mudskippers showed high concentration of PUFA namely 18:2ω6 (linoleic acid, LA), 20:4ω6 (arachiodonic acid, AA), 20:5ω3 (EPA) and 22:6ω3 (DHA) acids. It also contained high w-3 highly unsaturated fatty acid series. The arachiodonic acid (20:4ω6, AA) content was specially high in mudskippers and it is an essential precursor for the prostaglanding production in the body. Other neutral lipid classes such as sphingomyelin (responsible for child intelligence), triglyceride and cholesterol ester had been shown to be present in significant amounts. Mudskipper products in the form of ointment and medical paste are traditional sold in open markets.

Finger printing of potential commercial mudskipper species is essential for ensuring the individual or strain identification in order to get the required quality control and sustainable high production of the product. Genetic diversity of a given aquatic organisms (eg. mudskipper) is a measure of the possible choices of different information in a gene. When all or nearly all the members of a population have the same allele in the gene, that population is considered to have a low genetic diversity for that particular gene. If many variants exist in the gene sequence, that population is said to have a high genetic diversity at that particular gene. So, if genetic diversity is low for many gene of a species, that species or population is increasingly at risk, whereby the entire individual in the population is nearly identical. A population with high genetic diversity under adverse environment stress has a greater chance of survival. If genetic diversity is low, individuals in the population may not have the characteristic needed to cope with the new environmental conditions. As such the population may suddenly become extinct. The finger printing of the aquatic organisms also involves the occurrence of genetic segregation, gene mapping, gene selection information or percentage, identification markers linked to disease resistance gene, comparison of genetic DNA from tumour and normal tissue of the same individual (Kohno *et al.*, 1994; Scott *et al.*, 1997).

The Polymerase Chain Reaction (PCR) analysis on the local mudskipper *Periophthalmus schlosseri* in Peninsular Malaysia had revealed high genetic diversity in the Perlis population and a low genetic variability in the Terengganu population (Shamsudin *et al.*, 1999[c]). Small genetic distance among the Perlis and Penang populations was also detected (Shamsudin *et al.*, 1999[c]). Based on the position of each population in the dendogram, the Terengganu population (located in the east coast of Peninsular Malaysia) had been shown to cluster by itself, thus isolated from the rest of the populations which were located in the west coast of Peninsular Malaysia.

6. NUTRITIONAL STATUS AND QUALITY OF MARINE ENVIRONMENT

Patterns in phytoplankton seasonal-succession which are common in meso and eutrophic water bodies, can account for patterns in zooplankton species dynamics noted in field studies (Lundstedt and Brett, 1991). This is usually related to the nutritional quality of the phytoplankton. The quality of our indigenous water bodies can be reflected from the lipid and fatty acid profile of the ecosystem.

Common characteristics exist in the fatty acid (FA) compositions within the different phyla in the natural environment, but there is usually a variation in the fatty acid content both within and between species (Ackman *et al.*, 1968; Volkman *et al.*, 1989; Shamsudin, 1992; Shamsudin *et al.*, 1995). Flagellates and diatoms from natural ecosystem contain the long chained polyunsaturated fatty acid PUFA namely the eicosapentaenoic acid (EPA, 20:5ω3) and the docosahexaenoic acid (DHA, 22:6ω3), whereas green algae and some blue greens contain shorter FA of the ω3 type (such as linolenic acid, 18:3ω3), which are precursors to EPA and DHA (Watanabe *et al.*, 1983). The definite role of FA in aquatic food chain is unknown, but it is possible that the same FA are essential to numerous organisms. The marine rotifer *Brachionus* *plicatilis*, which is an important live food organism in aquaculture, has very little ability to produce high EPA and cladoceran species can grow best on flagellates which contain EPA and DHA (Lundstedt and Brett, 1991).

In the search for better understanding on the nutrients status of a marine as well as the nutritional quality of the natural tropical plankton present, samples have been collected from shallow coastal waters facing the South China Sea during the dry monsoon (May - September) and the wet monsoon (November - April) seasons (Shamsudin, 1999). The total fatty acid content of the predominantly phytoplankton communities (150 - 200 µm sieve nets) varied four to five fold with the lowest value occurring during the dry monsoon when blue-green became predominant. Saturated fatty acid content (SAFA), polyunsaturated fatty acid (PUFA) and total ω3 (Σω3) have shown the same seasonal pattern as the total fatty acid with high values in October to December 1993. Whenever the species of the dinoflagellate *Peridinium* and *Ceratium* were present in considerable amount, the docosahexaenoic acid DHA content is found to be high, especially from March to May. The maximum content of eicasopentaenoic acid EPA, total ω-3 fatty acid, PUFA and Σω3 in phytoplankton also occur during the pre-monsoon period (October and November 1993) when the diatoms are present in large amounts. The larger fraction sample (>200 µm sieve nets) which consist predominantly of zooplankton has high amounts of PUFA from September to November.

7. SATELLITE DETECTION OF PLANKTON BLOOM & WATER MASSES CIRCULATION

With the advance of satellite detection, the development of remote sensing and the associated advance in hydrology of optics, it is now feasible to describe ocean scale biogeochemical dynamics from satellite observation. The use of satellite data to identify chlorophyll blooms and to estimate sea surface dynamic height anomaly, so as to explain the water mass circulation as well as the geotropic force in the ocean has been widely employed to explain plankton transportations and blooms (Shamsudin *et al.*, 1999[de]; Shamsudin, 1999[abcd]). The occurrence of plankton is linked with the presence of fish and fishing grounds in the ocean. At present, at least 6 collaborative cruises (1985-1999) had been conducted in the South China Sea to gather data of various aspects of fishery resources and oceanographic parameters by the member countries (Malaysia, Thailand, Philippines and Vietnam) comprising of researchers from the universities and fishery departments of respective countries.

8. HARMFUL AGAE BLOOMS (HAB)

HAB is becoming important in coastal waters worldwide especially when it is related to fishery and coastal aquaculture (Shamsudin, 1996). The bloom comprises of vegetative cells that germinated from cysts. It will not form blooms unless conditions are conductive which include factors such as competitive advantage, release form nutrient limitation, favourable hydrographic conditions and release from predation. The red tide blooms of the dinoflagellate *Pyrodinium bahamense* in Sabah waters occur during stratified stable water column especially when there is a terrestrial input of organic selenite through land runoffs (Shamsudin *et al.*, 1995). Dinoflagellates do not like turbulence, as apposed to diatom blooms, which thrive under stratified calm condition. However, the tintinnid *Favella* is the predator on these toxic cells without adverse effects. The predation impact of these tintinnid is still unknown. A few patches of these species were observed during the SEAFDEC Cruise survey between 1985 to 1986 (Shamsudin *et al.*, 1999[de]).

9. BALLAST WATER FROM OIL TANKERS

The global transport of ballast water from ship tankers is estimated as 10 billion metric tons/y (Hallegraeff, 1984). The transport and transfer of harmful toxic non-indigenous planktonic microorganisms (especially dinoflagellates and diatoms) have already cause widespread ecological and environmental damage worldwide. Some of these ballast species (such as *Chaetoceros, Detonula, Ditylum, Heptocylindricus, Skeletonema, Thalassiosira*) can be cultured in the laboratories and they have resting spores. The minute ballast pennate diatom species of *Amphora*, *Navicula* and *Nitzschia* dan survive in the dark for many weeks as resting spores. Numerous toxic *Pseudonitzschia* species (namely *P. fraudulata, P. lineata, P. turgidula, P. subpacifica, P. multiseries, P. australis, P. seriata, P. purgens, P. cospidata*) can cause amnestic shellfish poisoning (ASP). *Pseudonitzschia multiseries* and *P. seriata* were encountered during the SEAFDEC Cruises 4 and 5 (Shamsudin *et al.*, 1999[e]).

10. INDICATOR SPECIES OF WATER MASSES

Studies on the minute species of Nanoplankton has not been emphasized and given priority due to its difficulty in identifying; however this should not lead to its neglect since it is responsible for >50% biomass carbon fixation and production in the ocean than the bigger size phytoplankton (Hallegraeff, 1984; Shamsudin, 1999[d]). The Nanoplankton species of *Minidiscus* and *Navicula* were encountered in abundance (1 - 6 x10^4 cell/L) in the South China Sea during the last two SEAFDEC cruises (1998 & 1999) and they occurred in definite water masses of know physico-chemical parameters as illustrated by the CCA (Canonical correspondence analysis). CCA is used to identify the environmental variables of the water masses that can account for the variations in plankton taxa. The tropical coccolithophorid of the South China Sea showed a dominance change from *Gephyrocapsa oceanica* to *Emiliania huxlegi* and a southward transport through water masses of many tropical species (especially *Scyphosphaera* sp.) during the SEAFDEC cruise 5 of the Philippines waters of the South China Sea.

The bottom ocean environment parameters in the Sulu Sea have been observed to be abnormally different from the rest of the surrounding ocean indicating that these water masses are actually isolated by underwater mountain ranges; these water masses have been in existence throughout the evolution in this planet probably for million of years. As such, phylogenetic population studies on various marine organisms from Sulu Sea need to be carried out in order to obtain information on the genetic variabilities segregation, mapping, selection, gene resistance and comparison with the recent related species.

SUMMARY

Through our understanding on the nutrient status of the ecosystem food chain involving a whole range of organisms (primary producers, herbivores, carnivores etc.), there is a great potential in utilizing these organisms as food added value resources for human as well as animal consumption, either through screening or cultivation of this organisms. Even though plankton is small in size, it is rich in nutritional value for growth, reproduction and survival rate. *Spirulina* which has been in existence in this planet for the last 3.5 billion years ago, is considered as the perfect food for human/animal consumption to restore health. The fish oil is another source of health food for human consumption. Human play an important role in ensuring the aquatic ecosystem is undisturbed and sustainable for many years to come for our survival in this planet. Satellite image has been widely used to gather the much needed information on fishery resources and oceanographic data.

References:

Ackman R.G., Jangaard P.M., Hoyle R.J., Brockerhoff H. (1964). Origin of marine fatty acids produced by the diatom *Skeletonema costatum. J. Fish. Res. Bd Can.*, 21: 747 - 756.

Ahlgren G, Lundstedt L., Breet M., Forsberg C. (1990). Lipid composition and food quality of some freshwater phytoplankton for cladoceran zooplankton. *J. Plankton Res.*, 12: 809 - 818.

Ahlgren G., Gustafsson 1-B., Boberg M. (1992). Fatty acid content and chemical composition of freshwater microalga. *J. Phycol.*, 18: 37 - 50.

Boberg M., Croon L.B., Gustafsson I-B., Bessby B. (1985). Platelet fatty acid composition in relation to fatty acid composition in plasma and to serum lipoprotein lipids in healthy subject with special reference to the linoleic acid pathways. *Clin. Sci.*, 68: 581 - 587.

Connor W.E., Connor S.1. (1986). Dietary cholesterol and fat and the prevention of coronary heart disease. Risks benefits of nutritional change. In: *Diet and Prevention of Coronary Heart Disease and Cance*r. Hallgren B., Levin 8, Rossner S., Vessby B. Eds. Ravel Press, New York, pp. 13 - 147.

Chu F.E., Dupuy D.J. (1980). The fatty acid composition of three unicellular algal species used as food sources for larvae of the American oyster (*Crassostrea virginica*). Lipids, 15: 356 - 364.

Dyerberg J., Bang H.Q., Hjorne N. (1977). Fatty acid composition of the plasma lipids in green land Eskimos. *Am. J. Clin. Nutr.*, 28: 958 - 966.

Dyerberg J., Bang H.Q. (1979). Hemostatic function and platelet polyunsaturated fatty acid in Eskimos. *Lancet* ii: 433 - 435.

Dyerberg J. (1982). Nutritional evaluation of long chain fatty acids in fish oils. In: *Nutritional Evaluation of Long Chain Fatty Acids in Fish Oil.*, ed. S.M. Barlow and M.E. Stansby, p. 245 - 261.

Dyerberg J., Bang H.Q., Stoffersen E., Moncada S., Vane J.R. (1978). Eicosapentaenoic acid and prevention of atherosclerosis? *Lancet* I: 117 - 119.

Dyerberg J. (1986). Linoleinate derived polyunsaturated fatty acids and prevention of atherosclerosis. *Nutr. Rev.*, 4: 125 - 134.

Hallegraeff, G.M. (1984). Coccolithophorids (calcareous Nanoplankton) from Australian waters. *Botanica marine* 27: 229 - 247.

Herold P.M., Kinsela J.E. (1986). Fish oil consumption and decreased risk of cardiovascular disease: a comparison of findings from animal and human feeding trials. *Am. J. Clin. Nutr.*, 43: 566 - 598.

Jones D.B., Davies T.M.E. (1982). Eicosapentaenoic acid and ischemi heart disease. *Lancet* I: 221 - 226.

Kagawa Y., Nishizawa M., Susuki M., Miyatake T., Hamamoto T., Goto K., Motonaga E., Izumikawa H., Hirata H., Ebihara A. (1982). Eicosapolyenoic acids of serum lipids of Japanese islanders with low incidence of cardiovascular disease. *J. Nutr. Sci. Vitaminol.*, 28: 441 - 453.

Kanazawa A. (1985). Nutrition of panaeid prawns and shrimps. In: *Proc. 1st Int. Conf. Cult. Penaeid Prawns Shrimps*. Taki Y., Ed. South East Asia Fisheries Development Centre, Iloilo, Philippines, pp. 123 - 130.

Kanazawa A., Teshima S.I., Kazuo O. (1979). Relationship between essential fatty acid requirements of aquatic animals and the capacity for bioconversion of linolenic acid to highly unsaturated fatty acids. *Comp. Biochem. Physiol* 63 B: 295 - 298.

Kenneth K.C. (1986). Biological effects of fish oils in relation to chronic diseases. *Lipids*, 21: 731 - 732.

Kinsella J.E. (1988). Food lipids and fatty acid: Importance in food quality, nutritional and health. *Food Technol.*; 42(10): 124 - 142.

Kohno T., Moroshita K., Takano H., Shapori D.N., Yakano J. (1994). Homozygous deletion at Chromosme 2q33 in human small-cell lung carcinoma identified by arbitrarily primed PCR genomic finger printing. *Oncogene*, 9: 103 - 108.

Langdon C.J., Waldock M.J. (1981). The effect of algal and artifical diets on the growth and fatty acid composition of *Crassostrea gigas* spat. J. *Mar. Biol. Assoc.* UK 61: 431 - 448.

Leaf A., Weber P.C. (1988). Medical progress, Cardiovascular effects of n-3 fatty acids. *N. Engl. J. Med.*, 318: 549 - 557.

Renaud S.M., Parry D.L., Thinh L.V., Kou C., Padovan A., Sammy N. (1991). Effect of light intensity on the proximate biochemical and fatty acid composition of *Isochrysis* sp. and *Nannochloropsis oculata* for use in tropical aquaculture. J. *Appl. Phycol.*, 3: 43 - 53.

Rodgers L.J., Barlow C.G. (1987). Better nutrition enhance survival of barramundi larvae. *Aus. Fish.*, 46(7): 30 - 32.

Palambad J. (1990). Fiskoljor och detinflammatoriska svaret (Fish oils and the inflammatory response). *Scand. J. Nutr.* (Naringsforskning), 34: 131 - 133 (English summary).

Scott W., Ihssen P.E., White B.N. (1997). Inheritance of RAPD molecular markers in lake trout *Salvelinus nameycush. Molecular Ecology*, 6: 609 - 613.

Shamsudin L. & Shazili N.A.M. (1991). Microplankton bloom in a brackish water lagoon of Terengganu. *Environmental Monitoring and Assessment*, 19: 287 - 294.

Shamsudin L. (1992). Lipid and fatty acid composition of microalgae used in Malaysia aquaculture as live food for the early stage of penaeid larvae. *J. Appl. Phycol.*, 4: 371 - 378.

Shamsudin L. (1993[a]). Biochemical composition and fatty acid content of zooplankton from tropical lagoon for larval rearing. *Journal Archives Internationales de Physiologie, de Biochimie et de Biophysique*, 101: 253 - 256.

Shamsudin L. (1993[b]). Biochemical composition of various food organism used in Malaysia aquaculture for mass propogation of fish larvae. *Acta Hydrobiologica*, 53: 11 - 17.

Shamsudin L. (1994[a]). Food values of indigenous zooplankton from the South China Sea on the East Coast of Peninsular Malaysia. *Journal of the World Aquaculture Society*, 25 (2): 208 - 231.

Shamsudin L. (1994[b]). Lipid and fatty acid composition of the indigenous zooplankton from Terengganu waters of the South China Sea. *J. Trop. Aquaculture* 9: 291 - 298.

Shamsudin L., Sleigh M. (1994[c]). Seasonal changes in composition and biomass of epilithic algal floras of a chalk and a soft water stream with estimates of production. *Hydrobiologia*, 273: 131 - 146.

Shamsudin L. (1995[a]). Lipid and fatty acid content microplankton bloom from tropical fish ponds. *Archives Internationales de Physiologie, Biochimie et Biophysique*, 103 (5): 21 - 27.

Shamsudin L. (1995[b]). Fatty acids profile of wild caught and culture fish juvenile of sea bass *(Lates calcarifer)*. *Acta Hydrobiologica*, 37 (1): 53 - 59.

Shamsudin L., Awang A., Ambak A., Ibrahim S. (1995[c]). Dinoflagellate bloom in a tropical fish ponds of coastal waters of the South China Sea. *Env. Monit. Assessment*, 40:303 - 331.

Shamsudin L. & Michael Sleigh (1995[d]). Seasonal changes in composition and biomass of epiphytic algae on the macrophyte *Ranunculus penicillatus* is a chalk stream, with estimates of production and observation on the epiphytes of *Cladophora glomerate. Hydrobiologia*, 306: 85 - 95.

Shamsudin L. (1996[a]). Lipid and fatty acid contents in red tides from tropical fish ponds of the coastal water of South China Sea. *Archives of Physiology and Biochemistry*, 104 (1): 36 - 42.

Shamsudin L., R. Faridah, Arif M.S. & Azmi M.A. (1996[b]). Is it scientifically justifiable that fish oil can solve heart problems. In: *Proc. 1st National Conference on Medical Sciences*, 13 (6): 1 - 3.

Shamsudin L., Mohd Arif Said, M. Azmi Ambak, Faridah Rashid (1996[c]). Source of fish oils with their lipid/fatty acid contents from selected local marine fish oils as health food for human/animal consumption. In: *Proceeding Joint Seminar on marine Science*. JSPS-VCC 6-8, Faculty of Fisheries Marine Science, UPM Serdang.

Shamsudin L., Yusof M., Azis A., Shukri Y. (1997[a]). The potential of certain indigenous copepod species as live food for commercial fish harvae rearing, *Aquaculture*, 151: 351 - 356.

Shamsudin L. (1998[a]). Seasonal variation of fatty acid content in natural microplankton from the Tumpat coastal waters of the South China Sea. *Arch. of Physiology and Biochemistry*, 106 (3): 253 - 260.

Shamsudin L. (1999[a]). Nanoditom and flagellate community structure in the waters of Western Philippines of the South China Sea. In: *Proceeding of the Malaysian Science and Technology Congress*, p. 101 - 101.

Shamsudin L. (1999[b]). Lipid and fatty acid content in natural microplankton from the Sri Tujuh (Kelantan) coastal waters of the South China Sea - environmental, nutrient status indicator. In: *Proceedings of the Japan Society for the Progress of Science* JSPS, p. 91 - 98.

Shamsudin L. (1999[c]). Coccolithophorids (nanoplankton) of the South China Sea - its mass water transport. In: *Proceeding of the International Conference on the International Oceanographic Data & Information Exchange in the Western Pacific* (IODS - West Pac.) 1999, p. 39 - 49.

Shamsudin L. (1999[d]). Marine Coccolithophorids (calcareous nanoplankton) from the South China Sea. In: *Proceedings of the Malaysian Science and Congress*, p. 30 - 39.

Shamsudin L. (1999[e]). Biochemical and other valuable Composition of *Dunaliella* - like isolate grown in liquid effuent from fish ponds. *Acta Hydrobiologica*, 41 (1): 95 - 101.

Shamsudin L. (1999[f]). Nutrition quality of selected algae used as lived feed in Malaysian aquaculture. *Assessment & Monitoring of Marine System*. International Marine Science Conference. S. Lokman, M.S.N. Azhar, M.S. Nasir & M.A. Borowitzka (eds.), Universiti Putra Malaysia Terengganu, p. 214 - 219.

Shamsudin L. & Kartini M. (1999). Nanoplankton distribution and abundance in waters of western Philippines of the South China Sea. In: *Proceeding of the 3[rd] Technology Seminar on Marine Fishery Resource Survey in SCS*, p. 274 - 289.

Shamsudin L., Saad C.R., Faridah A.R., & Said M.A. (1999[a]). Commercialisations of natural extracted eel oil as health food for human Consumption. *Assessment & Monitoring of Marine System*. S. Lokman, M.S.N. Azhar, M.S. Nasir & M.A. Borowitzka (eds.), Universiti Putra Malaysia Terengganu, p. 41 - 49.

Shamsudin L., Che Ros Saad, Faridah A.R. & Said M.A. (1999[b]). Commercialisations of natural extracted eel oil as health food for human Consumption. *Assessment & Monitoring of Marine System*. International Marine science Conference, S. Lokman, M.S.N. Azhar, M.S. Nasir & M.A. Borowitzka (eds.), Universiti Putra Malaysia Terengganu, p. 1 - 6.

Shamsudin L., Faridah A.R. & Said M.A. (1999[c]). Polyunsaturated fatty acid PUFA from aquatic source as health supplementary feed or food. In: *5[th] National Conference on Medical Science, School or Medical Science Kubang Kerian, Kelantan*, p. 1 - 9.

Shamsudin L., Hamid Y., Solahudin A.R. & M.Y. Shukri (1999[d]). Microplankton (including dinoflagellate, foraminefera) in the South China Sea, Area I; Gulf of Thailand and Peninsular. In: *Proceeding of the 1[st] Techniques Seminar on Marine Fishery Resource Survey in* SCS, p. 310 - 335.

Shamsudin L., Yasin A.H., Solahudin A.R. & Shukri M.Y. (1999[c]). Microplankton in the South China Sea, Area II; Sarawak, Sabah & Brunei Waters. In: *Proceeding of the 2[nd] Technology Seminar on Marine Fishery Resource Survey in SCS*, p. 197 - 223.

Simpoulos A.P., Kifer A.R., Marine R.E. (1986). *Health effects of polyunsaturated fatty acid in seafoods*. New York: Academic Press. 120p.

Syed M.A., Shamsudin L. & Abas N. (1999). Phospholipid distribution in Malaysian Fish. *Assessment & Monitoring of Marine System*. S. Lokman, M.S.N. Azhar, M.S. Nasir & M.A. Borowitzka (eds.), Universiti Putra Malaysia Terengganu, p. 130 - 137.

Volkman J.K., Jeffrey S.W., Nichols P.D., Rogers G.I., Garland C.D. (1989). Fatty acid and lipid composition of 10 species of microalgae used in mariculture. *J Exp. Mar. Bio. Ecol.*, 128: 219 - 240.

Watabane T., Ohta M., Kitajima C., Fujita S. (1982). Improvement of dietary value of brine shrimp *Artemia salina* for fish larvae by feeding them with $\omega 3$ highly unsaturated fatty acids, *Bull. Jap. Soc. Sci. Fish.*, 48: pp. 1775 - 1782.

Watanabe T., Kitajima C., Fujita S. (1983). Nutritional values of live organisms used in Japan for mass propagation of fish. A review. *Aquaculture*, 34: 115 - 143.

Watanabe T., Tamiya T., Oka A., Hirata M., Kitajima C., Fujita S. (1984). Improvement of dietary value of live foods for fish larvae by feeding them $\omega 3$ highly unsaturated fatty acids and fat soluble vitamins. *Bull. Jap. Soc. Fish.*, 49: 471 - 479.

FASCINATION

لَا حَوْلَ وَلَا قُوَّةَ إِلَّا بِاللهِ الْعَلِيِّ الْعَظِيمِ

No ability nor strength except with the help of the Al-Might - narrated by S.A.W.

فَلَا تَعْلَمُ نَفْسٌ مَّا أُخْفِيَ لَهُم مِّن قُرَّةِ أَعْيُنٍ جَزَاءً بِمَا كَانُوا يَعْمَلُونَ

Nobody knows what delights of the eye are kept hidden as reward for their good deeds.

(Sajadah 32 : 17)